

A Human-Machine Interface for Nontechnical Remote Waste-Sorters

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The Mixed Waste Management Facility (MWMF) at the Lawrence Livermore National Laboratory (LLNL) was designed as an integrated pilot-scale facility to bridge the gap between mature, bench-scale proven technologies and full-scale treatment facilities. As an integrated facility, technologies are being demonstrated to cover the entire treatment train from waste receipt to output of the final waste form and effluents. Telerobotics was chosen for deployment in MWMF for container handling, waste characterization and preliminary sorting during front-end handling operations.

One of the primary drivers in the decision to deploy telerobotics was the promise of improved productivity over standard teleoperation systems. Therefore, a primary goal of the telerobotics effort was to design an operator interface that allowed very efficient transitions between teleoperated and autonomous tasks, sufficient autonomy to increase productivity over a teleoperated system, and enough simplicity to allow the system's use by a wide range of waste handling personnel without incurring a significant training burden. An additional requirement was to design the system using as many off-the-shelf technologies and components as possible to meet the Office of Waste Management (EM-30) budget guidelines for our "austere" project. The combination of these factors posed some interesting challenges and compromises that have been met using several innovative approaches to the operator interface.

The telerobotic sorting system was designed for remote handling of low-level organic mixed wastes. As such, the primary hazards are potentially uncharacterized chemicals and low-level radioactivity. Therefore, the operator interface takes advantage of the ability to use direct viewing as the primary mechanism for visual feedback. To maintain a clear view of the work cell, the operator console and displays were configured to allow flexibility in the placement of displays and their number was minimized to only that required for efficient system operation. To minimize training requirements and address concerns about computer literacy and having computer-savvy operators, the system has been designed without computer keyboards, relying on a speaker-independent voice-recognition system tailored to the application. The use of a mini-master type hand-controller was dictated by budget considerations. An innovative hybrid position/force-velocity input control law minimizes the need to constantly reindex the hand-control to accommodate the difference between the work-cell size and the hand-control work volume. The resulting human-machine interface provides a very wide range of functionality including:

- master position/force to tele-robotic position/rate control
- viewpoint dependent master-manipulator device correspondence
- operator force queuing (application-specific force-reflection)
- 6-DOF, dominant-axis, and fixed-orientation motion control modes
- autonomous override of operator commands for collision avoidance and force compliance
- autonomous motion control
- automatic logging of waste item characterization information
- automatic selection of appropriate disposal bin and real-time path planning
- visual confirmation of recognized voice commands

The interface is currently being used to control a Schilling Titan III manipulator and a Cybernet force reflecting master controller in a plant-prototypic waste sorting demonstration cell. The system has been in use for several months and is currently being tested by operators with little or no robotics background and essentially no training. This paper discusses the human-machine interface and the system results to date.

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